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The Biology and Control of Turf Grubs

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THE BIOLOGY AND CONTROL OF TURF GRUBS

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Turf areas in Ohio are subject to damage by at least three different kinds of grubs. The three types of grubs which occur most commonly and cause the greatest damage are grubs of the Japanese beetle, *Popillia japonica* Newm., the northern masked chafer, *Cyclocephala borealis* Arrow, and the various species of June beetles, *Phyllophaga* spp.

Adults of the Japanese beetle and the various species of June beetles attack the foliage of plants while the grubs of all three feed upon the roots of grasses. The adults of the northern masked chafer are not known to feed upon foliage. If the adults of the Japanese beetle are present in considerable numbers on the foliage of plants, grubs can usually be found in the turf.

On the other hand, the adults of the June beetles may not cause any noticeable defoliation to the various trees in an area even though the grubs may be causing considerable damage to turf. The northern masked chafer is somewhat sporadic in its behavior. Grubs of this species may cause severe damage to a particular area for 1 or 2 years and then for some unexplained reason may practically disappear from the scene.

JAPANESE BEETLE

Japanese beetle adults usually appear on the foliage about the third week in June. These beetles are about ½ inch long and ¼ inch wide. The head, thorax, and abdomen are metallic-green in color while the hard outer wings are coppery-brown. There are two tufts of white hair on the abdomen just behind the wing covers and five tufts along each side of the body. Adults are mid-day fliers, their period of greatest activity being from about 9 a.m. to 4 p.m. The female beetle feeds on foliage a few days after emerging before it enters the turf to lay from one to four eggs. It then emerges again and, after feeding a few more days, returns to the soil to deposit another batch of eggs. This procedure continues until a total of from 40 to 60 eggs have been deposited. All eggs are laid about 2½ inches beneath the surface. The life time of the beetle is from 30 to 45 days.

The eggs are nearly spherical in shape, 1/16 to ⅛ inch in diameter, and are white when first laid changing to cream color before hatching. Eggs are deposited in the soil and hatch into tiny grubs in about 10 days.

The grubs immediately begin to feed on the humus in the soil and on the roots of various plants. As the grubs increase in size, they work their way close to the soil surface where they continue to feed on the roots of grasses causing the grass to die out in small patches. By the latter part of September or upon the approach of cold weather, the grubs, which by that time are about one inch long and are white to greyish-white in color, gradually move downward in the soil where they spend the winter. The depth to which they migrate undoubtedly is affected by temperature, soil type, and soil moisture but usually it varies from 6 to 14 inches. In late March or early April of the following year, the grubs again approach the soil surface to continue their feeding. In the latter part of May, they change into the pupal stage.

The pupa is cream-colored, bobbin-shaped, and about ½ inch in length. It is from this stage that the insect transforms into the adult beetle. The life cycle of this species requires one year. The different stages that the Japanese beetle passes through during the year are shown in Figure 1.

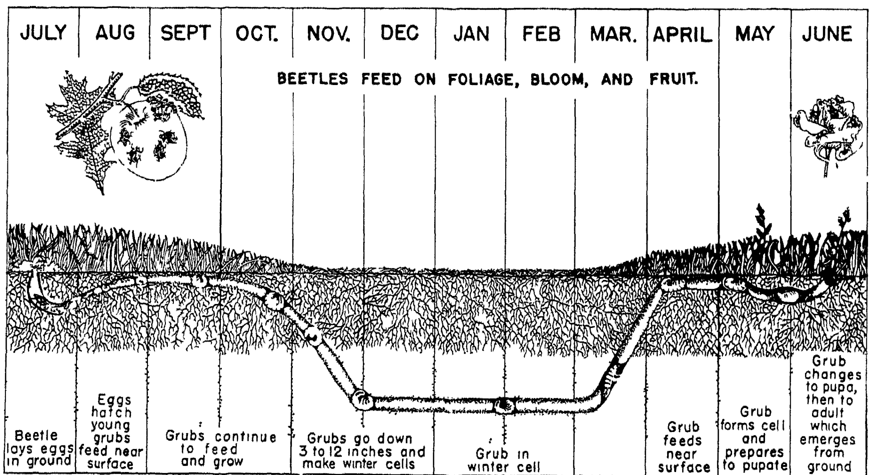

CHART SHOWING THE DIFFERENT STAGES OF JAPANESE BEETLE THROUGHOUT THE YEAR

Fig. 1.—Life history of the Japanese beetle.

This insect is not present in epidemic numbers through Ohio and hence its damage is confined to a relatively small area in the state. However, it is present in sufficient numbers in several areas to afford an excellent opportunity to evaluate the effectiveness of insecticides in controlling the grubs. Grub control tests were set up in turf areas where grub populations averaged seven or more grubs per square foot. In most instances, the plots were located in public parks, cemeteries, and golf courses.

A great many insecticides have been tested for Japanese beetle grub control. All of these materials have been used, at one time or another, as wettable powders, emulsifiable concentrates, and granular forms. Wettable powders were applied mixed with water or with milorganite as a carrier. The emulsifiable formulations were mixed with water in all cases. Free-flowing granular materials were mixed with milorganite or applied without a carrier.

Liquid applications to small plots of less than 300 square feet were made with a hand sprinkling can and to larger plots with a power sprayer equipped with a boom or cluster of jet nozzles. Dry materials were applied to the soil surface with a small 18-inch fertilizer spreader, a hand sifter, or a cyclone seeder.

The plots were arranged in randomized blocks and varied in size from 100 square feet to one acre. All treatments were replicated, the number of replicates varying with the nature of the test.

In small plot work (100 square feet) there were usually four replicates, but in large plots (1 acre) there were only two or three.

The data were obtained by examining the soil for larvae in three 1/3 square foot samples in plots of 100 square feet in size. More samples were examined for grubs in the larger sized plots. The 1/3 square foot cores were taken to a depth of four or more inches, depending upon the depth of the larvae at the time of the survey.

Figure 2 shows the type of sampler used, the size of the soil core obtained with each bite of the sampler, and the portable table used in looking through the soil for the larvae.

In general, the insecticide program was set up to determine the residual effect over a long-time period. However, in a few instances efforts were made to speed up the initial kill of grubs. To determine the speed of kill, grub population records were usually taken within about 30 days of application date. Subsequent records to measure residual effectiveness were taken either in September or October of one year or in April or May of the next.

Fig. 2.—Equipment used in sampling for grub population.

The insecticides used and the resulting grub populations obtained at various times are summarized in the following tables.

In 1945 an experiment was initiated to compare the effectiveness of DDT and the previously recommended lead arsenate for the control of the Japanese beetle larvae. DDT was applied at three different levels and lead arsenate at the recommended rate to plots 100 square feet in size. Population records were taken at intervals throughout the investigational period as shown in Table 1. The 1957-58 survey was conducted on the thirteenth generation of the insect exposed to the insecticide.

These data indicate that all levels of DDT used were more effective than lead arsenate. They also show that lead arsenate ceased to give control of Japanese beetle grubs after being in the soil for five generations of the insect. The 12.5 pound rate of DDT began to show some deterioration after being in the soil for six generations and continued to decrease in effectiveness finally becoming only 50 percent effective at the end of the thirteenth generation. The 25 pound rate of DDT began to show some deterioration in the seventh generation and continued to

TABLE 1.—Japanese beetle control in turf, Washington Park, Newburgh Heights, Ohio. Treatments applied October 2, 1945

Insecticide	Rate in lbs. actual per acre	Population per Square Foot								
		June 8, 1946	Oct. 1, 1946	May 16, 1948	May 16, 1949	Oct. 16, 1950	Oct. 12, 1951	Oct. 13, 1952	Oct. 9, 1953	Oct. 9, 1957
DDT	12.5	2.6	.0	.0	.0	1.8	6.2	2.0	1.3	4.3
DDT	25.0	1.0	.0	.0	.0	.0	.8	1.0	1.8	2.5
DDT	37.5	4.4	0	.0	.0	.0	.0	.0	.0	.0
Lead arsenate	435.0	4.8	2	1.0	3.6	21.8	23.0	2.0	7.3	12.8
None	----	12.8	14.2	14.8	13.0	34.0	22.4	8.2	11.3	8.8

decrease in effectiveness giving only 72 percent control at the last survey date. The 37.5 pound rate gave excellent control throughout the period studied. Surveys were not conducted in these plots between 1954 and 1957 because of a low grub population in the untreated areas.

In 1946 two insecticides were initially evaluated for the control of the Japanese beetle grubs in turf. The survey results are shown in Table 2. This test has been in operation through 12 generations of the insect.

TABLE 2.—Japanese beetle control in turf, Forest Hill Park, East Cleveland, Ohio. Treatments applied September 6, 1946

Insecticide	Rate in lbs. actual per acre	Population per Square Foot						
		Oct. 14, 1946	May 11, 1948	May 17, 1949	Oct. 30, 1950	Oct. 16, 1951	Oct. 16, 1952	Oct. 10, 1957
Lead arsenate	435	13 8	.0	.0	.0	.3	.0	.0
DDT	25	16.8	.0	.0	.0	.0	.0	.0
BHC	.25	21.4	.7	4.4	12.8	18.3	10.0	4.8
BHC	2.5	6.0	.0	.2	1.8	9.3	6.0	5.0
BHC	5.0	9.2	.0	.0	1.2	2.0	2.5	2.3
BHC	10.0	3.4	.0	.0	.0	1.3	1.0	.0
Chlordane	25.0	4.6	.0	.0	.0	.0	.0	.0
Chlordane	15.0	3.8	.0	.0	.0	.0	.0	.0
Chlordane	5.0	6.8	.0	.0	.0	.0	.0	.0
Chlordane	1.0	13.2	.0	.2	.2	6.8	2.3	4.0
None	----	18.4	.0	.5	6.6	20.0	7.5	5.5

In this series of plots, lead arsenate applied at the rate of 435 pounds per acre and DDT at the rate of 25 pounds of actual material gave excellent control for 12 generations of the insect. The same is true of the 10 pound rate of BHC and the 5, 15, and 25 pound rates of chlordane. The one pound rate of chlordane began to show considerable deterioration after being in the soil for six generations of the insect. The data would indicate that the ¼ pound rate of BHC gave no control during this period and the 2.5 and 5 pound rates began to lose their effectiveness in the sixth generation and were ineffective in the twelfth generation.

TABLE 3.—Residual effectiveness of lead arsenate applied to turf in Riverside Cemetery, Cleveland, Ohio, October 31, 1947

Insecticide	Rate in lbs. actual per acre	Population per Square Foot					
		May 4, 1948	May 16, 1949	May 10, 1951	Oct. 19, 1951	Oct. 14, 1952	Oct. 9, 1957
Lead arsenate	435	4.4	.0	1.2	2.4	.0	4.8
Lead arsenate	870	3.4	.0	.0	.6	.0	2.8
Lead arsenate	1305	1.6	.0	.0	.2	.0	.8
None	----	20.0	13.0	14.8	13.8	7.4	8.8

The data in Table 3 were obtained from plots that were established for the purpose of determining the effectiveness of lead arsenate when applied at three different levels to plots of 100 square feet in area. The different rates of lead arsenate have been in the soil for 11 generations of the Japanese beetle.

These data indicate that the 435 pound rate began to show some deterioration in the fourth generation and the other two rates in the fifth generation. However, a year later no grubs were found in any of the treated plots. In the eleventh generation, the 435 pound rate reduced the Japanese beetle population about 45 percent, the 870 pound rate by 68 percent, and the 1305 pound rate by 91 percent. In reviewing the data in Tables 1, 2, and 3, it can be noted that considerable variation occurred in the results obtained with lead arsenate. The differences were probably due to differences in soil constituency or its ability to retain the toxicant.

Table 4 shows the comparative value of DDT and chlordane applied at different levels for the control of the Japanese beetle larvae. These insecticides have been in the soil for 10 generations of the insect.

TABLE 4.—Japanese beetle control in turf, Springhill Cemetery, Wellsville, Ohio. Treatments applied April 11, 1949

Insecticide	Rate in lbs. actual per acre	Population per Square Foot					
		Sept. 30, 1949	Oct. 4, 1950	Oct. 8, 1951	Oct. 2, 1952	April 11, 1957	Oct. 2, 1957
DDT	12.5	1.8	1.8	.8	.0	.0	2.5
DDT	25.0	.5	.8	.3	.0	.0	.0
Chlordane	5.0	.0	.0	.0	.0	.0	.0
Chlordane	10.0	.0	.0	.0	.0	.0	.0
None	----	17.5	21.0	19.8	10.0	22.3	26.3

These data show that the 5 and 10 pound rates of chlordane and 25 pound rate of DDT were still giving perfect control of the Japanese beetle grubs after being in the soil for 10 generations of the insect. The 12.5 pound rate of DDT began to show deterioration in the tenth year being only 91 percent effective on the last survey date. It should be pointed out also that in this test all materials gave effective control of the 1949-50 generation when the toxicants were applied in April of 1949.

Data shown in Table 5 were obtained from plots that were established for the purpose of determining the effectiveness of various insecticides in controlling the Japanese beetle grubs and to compare these results with those obtained from a similar set of plots that were established two months earlier. These insecticides have been in the soil for nine generations of the insect.

TABLE 5.—Japanese beetle control in turf, Springhill Cemetery, Wellsville, Ohio. Treatments applied June 9, 1949

Insecticide	Rate in lbs. actual per acre	Population per Square Foot				
		Sept. 30, 1949	Oct. 4, 1950	Oct. 8, 1951	Oct. 2, 1952	Oct. 2, 1957
DDT	12.5	4.5	.5	.3	.0	.8
DDT	25.0	3.3	4.5	.8	.0	.0
Chlordane	5.0	.0	.0	.0	.0	.0
Chlordane	10.0	.0	.0	.0	.0	.0
None	----	13 3	12.5	15.3	5.5	25.0

The 1957 survey results are similar to those obtained in the previous test (Table 4), except that a larger number of grubs were found in the DDT plots in the 1949-50 survey of this test than were found in the similar plots of the previous test established two months earlier. No difference existed in the chlordane plots which indicates that effective control of the Japanese beetle grubs can be obtained in the fall in areas that are treated as late as the previous June 9.

Results shown in Table 6 were obtained from plots that were established for the purpose of determining the effect of insecticides on the current grub population when they are applied at the time a majority of the grubs are in the first or second instars. Insecticides and rates of application used in this test were the same as those used in the two previous tests. Parathion was included in the test in order to determine if a quicker kill could be obtained than obtained with the chlorinated hydrocarbons. Although the test was set up to determine immediate effects, the plots were continued for a number of years. These materials have been in the soil for nine generations of the Japanese beetle, and grub population records were taken five different years.

TABLE 6.—Japanese beetle control in turf, Springhill Cemetery, Wellsville, Ohio. Treatments applied August 10, 1949

Insecticide	Rate in lbs. actual per acre	Population per Square Foot				
		Sept. 30, 1949	Oct. 4, 1950	Oct. 8, 1951	Oct. 2, 1952	Oct. 2, 1957
DDT	12.5	5 3	2.0	.0	.0	.0
DDT	25 0	8 0	.8	.0	.0	.0
Chlordane	5 0	1 3	.0	.0	.0	.0
Chlordane	10.0	.8	.0	.0	.0	.0
Parathion	1.0	1.8	5.3	7.5	6.0	23.0
Parathion	5.0	.3	4.8	9.0	5.8	20.5
None	----	14.8	15.0	22 8	7.3	23.3

The survey results obtained from this series of plots are similar to those obtained in the two previous tests except that more grubs were found in the 1949-50 survey of this test than in the two previous tests shown in Tables 4 and 5.

In comparing the data in Tables 4, 5, and 6, it is found that in the 1949-50 surveys the April applications were more effective in reducing the grub population than the June applications and that the June applications were more effective than the August applications. However, in all three tests, the grub population in the insecticide plots was significantly lower than that found in the untreated plots. These data indicate that an insecticide applied as late as August 10 would prevent severe turf damage the following September and October, but even the best treatments made that late will not eliminate the current season's grubs completely.

The data in Table 7 were obtained from plots that were established for the purpose of determining the effectiveness of heptachlor in controlling the Japanese beetle grubs. This test has been in operation through nine generations of the insect.

TABLE 7.—Japanese beetle control in turf, St. Elizabeth Cemetery, Wellsville, Ohio. Treatments were applied June 8, 1949

Insecticide	Rate in lbs. actual per acre	Population per Square Foot							
		Sept. 19, 1949	Sept. 29, 1950	Oct. 5, 1951	Oct. 1, 1952	Oct. 12, 1953	April 16, 1956	April 11, 1957	Oct. 2, 1957
Heptachlor	1	.2	2.8	.2	.0	.0	.0	1.2	.0
Heptachlor	5	.0	.0	.0	.0	.0	.0	.0	.0
Heptachlor	10	.0	.0	.0	.0	.0	.0	.0	.0
Heptachlor	20	.0	.0	.0	.0	.0	.0	.0	.0
None	—	18.2	9.0	9.8	5.8	5.0	8.2	26.4	29.8

Despite the fact that a few grubs were found in plots of the one pound rate at different times during the nine generation period, this level still gave effective control throughout the period. It is interesting to note also that not a single grub was found in the 5, 10, and 20 pound levels in any of the eight annual surveys in spite of the fact that the check plots had a good population each year.

Table 8 summarizes the results obtained from plots that were established for the purpose of getting more information regarding the effectiveness of the different levels of chlordane in controlling the Japanese beetle larvae. In this test the different levels of chlordane have been in the soil for eight generations of the insect.

TABLE 8.—Japanese beetle control in turf, Belleview Golf Course, Steubenville, Ohio. Treatments applied May 11, 1950

Insecticide	Rate in lbs. actual per acre	Population per Square Foot		
		Sept. 11, 1952	Oct. 4, 1955	May 1, 1957
Chlordane	1	.0	.3	4.3
Chlordane	5	.0	.0	.0
Chlordane	10	.0	.0	.0
Chlordane	15	.0	.0	.0
Chlordane	20	.0	.0	.0
Chlordane	25	.0	.0	.0
None	--	15.8	30.8	32.3

The grub population has varied to such an extent, due to weather, that these plots were surveyed only three times during the period the insecticides have been in the soil. In the 1956-57 generation, after being in the soil for eight generations of the insect all levels of chlordane gave excellent control of the grubs. Even the one pound rate gave an 87 percent reduction in population in the eighth generation.

The data in Table 9 were obtained from plots that were established for the purpose of determining the effectiveness of isodrin and endrin in controlling larvae of the Japanese beetle. These insecticides were applied at four different levels, as shown in column one, and at the present time they have been in the soil for six generations of the insect.

TABLE 9.—Japanese beetle control in turf, Vegetable Crops Substation, Marietta, Ohio. Treatments applied August 8, 1952

Insecticide	Rate in lbs. actual per acre	Population per Square Foot					
		Sept. 22, 1952	Sept. 30, 1953	Sept. 7, 1954	Sept. 12, 1955	Sept. 20, 1956	Oct. 7, 1957
Isodrin	1	8 5	.5	8.3	.8	12.8	1.5
Isodrin	5	1.2	.0	.0	.0	.0	.0
Isodrin	10	.0	.0	.0	.0	.0	.0
Isodrin	20	.2	.0	.0	.0	.0	.0
None	--	21.8	22.5	16.7	21.5	23.0	4.0
Endrin	1	7.0	.0	.0	.8	7.3	4.0
Endrin	5	1.3	.0	.0	.0	.0	.0
Endrin	10	.0	.0	.0	.0	.0	.0
Endrin	20	.0	.0	.0	.0	.0	.0
None	--	25.5	20 8	9.3	20 0	19.5	3.8

These data indicate that these two insecticides were similar in their effectiveness and both gave excellent results in the control of the Japanese beetle grubs when applied at a rate of as much as five pounds of the actual material per acre.

Data shown in Table 10 were obtained from plots that were established to determine the effectiveness of insecticides in controlling grubs of the northern masked chafer. Inasmuch as the first survey revealed the presence of Japanese beetle larvae, data were also taken on the control of this insect. These insecticides have been in the soil for six generations of the species.

TABLE 10.—Japanese beetle control in turf, East Liverpool Country Club, East Liverpool, Ohio. Treatments applied April 23, 1953

Insecticide	Rata in lbs. actual per acre	Population per Square Foot				
		May 21, 1953	April 27, 1954	April 19, 1955	April 22, 1957	Oct. 4, 1957
Toxaphene	6	1.5	5.5	1.0	.0	.0
Toxaphene	18	1.0	1.5	.5	.0	.0
Dieldrin	1	1.5	.0	.0	.0	.0
Dieldrin	5	1.0	.0	.0	.0	.0
None	--	1.5	3 5	21.5	26.4	8.0

These data show that the two levels of toxaphene were less effective than dieldrin in the 1954 and 1955 surveys. Thereafter, all levels of the two materials were highly and equally effective in controlling the Japanese beetle grubs. The data also indicate that the Japanese beetle grub population increased from the time of the first survey to the last. The low population in the check plots in the 1957 survey is undoubtedly due to the hot dry weather that prevailed in July and August of 1957. It should be noted that the data under the column headed May 21, 1953 were obtained when the plots were surveyed 28 days after the insecticides were applied. These results indicate that the insecticides used were not effective in reducing the Japanese beetle population in that short period of time.

An experiment was initiated in 1953 to compare the effectiveness of aldrin and dieldrin with that of lead arsenate, toxaphene, and heptachlor for the control of the Japanese beetle larvae. These studies have been carried on for five generations of the insect and the results are shown in Table 11.

TABLE 11.—Japanese beetle control in turf, New Matamoras Cemetery, New Matamoras, Ohio. Treatments applied October 21, 1953

Insecticide	Rate in lbs. actual per acre	Population per Square Foot				
		April 19, 1954	Sept. 8, 1954	May 3, 1956	Sept. 20, 1956	Oct. 7, 1957
Lead arsenate	435	3.4	.0	.3	.0	.3
Aldrin	3.5	18.4	.0	.0	.0	.0
Dieldrin	3	12.4	.0	.0	.0	.0
Toxaphene	24	22.4	.0	.0	.3	.0
Heptachlor	5	14.7	.0	.0	.0	.0
None	--	20.7	8.0	1.7	13.4	5.7

The data show that aldrin and dieldrin are similar to the other insecticides in regard to their initial effectiveness against the grubs that were in the soil at the time of the insecticide application. These results indicate that all of the chlorinated hydrocarbon insecticides used in the test were very effective in controlling grubs in turf throughout the period of observation.

Data in Table 12 were obtained from plots that were established for the purpose of determining the relative value of applying insecticides in a liquid or dry form. The liquid applications were made by mixing the emulsifiable formulation with water and applying with a sprinkling can, and the dry applications were made by mixing the wettable powders with milorganite and applying with a fertilizer spreader. These insecticides have been in the soil for three generations of the insect.

TABLE 12.—Japanese beetle control in turf, Madison Country Club, Madison, Ohio. Treatments applied August 12, 1954

Insecticide	Rate in lbs. actual per acre	Form applied	Population per Square Foot		
			Sept. 28, 1954	Sept. 29, 1955	Oct. 8, 1956
DDT	25	Dry	3.5	11.4	28.5
	25	Liquid	2.5	11.4	16.5
Chlordane	10	Dry	.5	1.0	3.0
	10	Liquid	2.5	.4	1.0
Aldrin	3	Dry	2.0	3.4	2.5
	3	Liquid	1.0	.0	3.0
Dieldrin	3	Dry	.0	3.7	6.0
	3	Liquid	.0	2.7	2.0
Heptachlor	3	Dry	3.5	.4	1.5
	3	Liquid	2.0	1.0	.0
Endrin	3	Dry	5.5	3.4	.5
	3	Liquid	1.0	1.0	1.5
Isodrin	3	Dry	7.5	1.0	5.5
	3	Liquid	.0	.0	.5
Toxaphene	25	Dry	3.5	1.8	1.0
	25	Liquid	.0	1.0	7.5
None	--	----	2.0	10.3	24.5

The average grub population in each of the treated plots is significantly different from that of the untreated plots except for the 1954-55 survey and for the DDT plots. No significant difference was found between the dry and the liquid applications. The reason for the poor results in all of the plots as compared to the results obtained elsewhere in the state with the same insecticides cannot be explained at the present time. However, it is possible that the decreased effectiveness was due to the fact that the soil in these plots is almost pure sand which retains water for only a short period of time.

Results shown in Table 13 were obtained from plots that were established for the purpose of obtaining more information regarding the effectiveness of lead arsenate and toxaphene in another location in the state. These insecticides have been in the soil for four generations of the insect.

TABLE 13.—Japanese beetle control in turf, Cambridge Cemetery, Cambridge, Ohio. Treatments applied August 27, 1954

Insecticide	Rate in lbs. actual per acre	Population per Square Foot			
		May 17, 1955	May 23, 1956	Sept. 26, 1956	Sept. 18, 1957
Lead arsenate	435	10.3	.3	.0	.0
Lead arsenate	870	4.3	.0	.0	.0
Toxaphene	25	2.0	.0	.0	.0
Toxaphene	75	1.3	.0	.0	.0
None	----	20.3	11.3	24.0	11.8

In comparing the data in Table 13 with those in Tables 10 and 11, it will be found that these materials have been equally effective in several locations in the state.

The data in Table 14 were obtained from plots that were established for the purpose of finding out if aerifying the soil prior to application of an insecticide would increase the rapidity of kill.

Chlordane and dieldrin were applied in a liquid form and the others in a dry form mixed with milorganite. All materials were applied immediately after the soil was aerified. These insecticides have been in the soil for three generations of the insect.

The data in the column headed October 3, 1955 were obtained by surveying the plots 33 days after application. Upon subjecting these data to analysis of variance, no significant difference in population was found between treatments. In this case, aerifying the plots before applying an insecticide was not effective in giving a more rapid kill of the larvae. However, all of the insecticides remained in the soil to give excellent control of the grubs in succeeding generations.

TABLE 14.—Japanese beetle control in turf, Thompson Park, East Liverpool, Ohio. Treatments applied August 30, 1955

Insecticide	Rate in lbs. actual per acre	Condition of turf	Population per Square Foot		
			Oct. 3, 1955	April 23, 1957	Oct. 3, 1957
Chlordane	10	Aerified	15.5	.0	.0
	10	Unaerified	24.0	.0	.0
Dieldrin	3	Aerified	14.5	.0	.0
	3	Unaerified	12.0	.0	.0
Isodrin	3	Aerified	25.5	.0	.0
	3	Unaerified	32.5	.0	.0
Endrin	3	Aerified	46.0	.0	.0
	3	Unaerified	25.5	.0	.0
Lead arsenate	435	Aerified	38.5	.0	5 6
	435	Unaerified	19.5	.0	4.5
None	----	Aerified	31.5	14.5	18.0
	----	Unaerified	55.5	14.8	20.3

Results shown in Table 15 were obtained from plots that were established in order to get more information regarding the effectiveness of chlordane in sandy soils. This material was applied at several rates some of which are lower than generally recommended. The different levels of chlordane in this test have been in the soil for three generations of the insect.

TABLE 15.—Japanese beetle control in turf, Blackbrook Golf Course, Painesville, Ohio. Treatments applied April 11, 1956

Insecticide	Rate in lbs. actual per acre	Population per Square Foot	
		April 24, 1957	Sept. 12, 1957
Chlordane	1.0	.0	7.5
Chlordane	2.5	.0	.0
Chlordane	5.0	.0	.0
Chlordane	7.5	.0	.0
Chlordane	10.0	.0	.0
None	----	9.0	34.5

These plots were not sampled in 1956 to get the effect of the insecticide on the 1955-56 generation. All levels of chlordane except the one pound rate gave excellent control for the short period the test has run.

Data in Table 16 were obtained from plots that were established for the purpose of determining the effectiveness of insecticides when a wetting agent, such as Aqua-gro, was added to the material used. The insecticides and rate of application are shown in column one and two in the table. Aqua-gro is designed to increase the wetting power in a liquid application. Therefore, it was thought that it might increase the rapidity of kill. These materials have been in the soil for three generations of the insect.

TABLE 16.—Japanese beetle control in turf, Union Cemetery, Toronto, Ohio. Treatments applied May 10, 1956

Insecticide	Rate in lbs. actual and gallons per acre	Population per Square Foot		
		June 7, 1956	May 2, 1957	Oct. 14, 1957
Chlordane	5 lbs.	5.5	.0	.0
Chlordane Aqua-gro	5 lbs. 10 gals.	7.0	.0	.0
Dieldrin	2 lbs.	8.0	.0	.0
Dieldrin Aqua-gro	2 lbs. 10 gals.	8.0	.0	.0
Heptachlor	2 lbs.	11.5	.0	.0
Heptachlor Aqua-gro	2 lbs. 10 gals.	12.5	.0	.0
None	----	25.3	18.8	4.0
Aqua-gro	10 gals.	26.3	24.3	1.8

The data in the column headed June 7, 1956 were obtained when the plots were surveyed 28 days after the insecticides were in the soil. These data indicate that Aqua-gro had no effect in increasing the rapidity of kill in this short period of time. In subsequent surveys all of the insecticides reacted in the same manner as they have in other tests.

The data shown in Table 17 were obtained from plots that were established to determine the effectiveness of granular insecticides when applied with a cyclone seeder. Using this dispenser it was possible to cover a swath 12 to 15 feet in width. The granular insecticides used in this test have been in the soil for three generations of the insect.

TABLE 17.—Japanese beetle control in turf, Union Cemetery, Toronto, Ohio. Treatments applied May 10, 1956

Insecticide	Rate in lbs. actual per acre	Population per Square Foot		
		June 7, 1956	May 2, 1957	Oct. 13, 1957
Chlordane	4.0	13.8	.0	.0
Dieldrin	1.7	15.9	.0	.0
Aldrin	1.7	15.6	.0	.0
None	--	19.8	9.0	4.0

The data in the column headed June 7, 1956 were obtained when the plots were surveyed 28 days after application. These results indicate that no control was obtained in this short period of time. The subsequent surveys would indicate that a uniform distribution was obtained with this method of application since the results are similar to those obtained from other methods of application.

NORTHERN MASKED CHAFER

The northern masked chafer is chestnut-brown in color and is covered with fine hairs. The adult beetles emerge from the soil during the latter part of June and early July. Adults are night fliers in habit and remain in the soil during the day. Unlike the Japanese beetle they are strongly attracted to light. Careful observations failed to find adult feeding of any kind.

Female adults begin to lay eggs in the soil within a few days after they emerge from the pupal case. Eggs of this beetle when laid are pearly-white and egg-shaped. The majority of them are laid between four and six inches below the soil surface. The eggs hatch into tiny grubs in about 20 to 22 days.

Tiny grubs begin to feed on the roots of plants and other organic material in the soil almost immediately after hatching. As the grubs increase in size they work their way close to the surface where they continue to feed upon the roots of grasses. About the middle part of October or at the onset of cold weather the grubs begin to descend in the soil where they spend the winter at a depth of 14 to 16 inches. When this occurs, the grubs are usually about 1¼ inches long. In the following spring the grubs begin to move upward and by early May all are feeding close to the surface. In early June they again begin to move downward in the soil but only go to a depth of about six inches where they transform to the pupal stage.

The pupa when newly transformed is creamy-white in color gradually turning to reddish-brown. It spends an average of 18 days in this stage. It is from this stage that the insect transforms into the adult beetle. The life cycle requires one year. Since the transformation does not occur at the same time for all individuals, there is an overlapping of the different stages. Figure 3 shows the different stages of the insect as they occur throughout the year.

Inasmuch as the northern masked chafer fluctuates greatly in abundance from year to year, experiments established solely to study the effectiveness of insecticides for the control of the insect seldom provided satisfactory data for more than a year or two before the insect disappeared from the area. Accordingly, the data shown in the following tables, in most cases, were obtained from tests that were established to study the effectiveness of insecticides in controlling larvae of the Japanese beetle.

Data shown in Table 18 were obtained from plots that were established to determine the effect of lead arsenate in controlling the Japanese beetle grub. These plots also provided an opportunity to study the effect of the toxicant on the northern masked chafer.

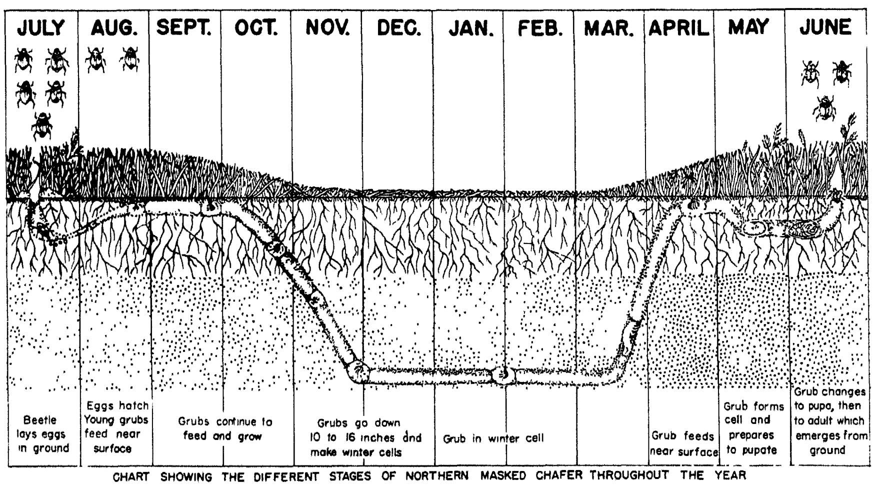

Fig. 3.—Chart showing progression of stages of the northern masked chafer and their location in the soil throughout the year.

TABLE 18.—Northern masked chafer control in turf, Riverside Cemetery, Cleveland, Ohio. Treatments applied October 31, 1947

Insecticide	Rate in lbs. per 1000 sq. ft.	Population per Square Foot			
		May 4, 1948	Oct. 14, 1952	Oct. 10, 1955	Oct. 9, 1957
Lead arsenate	10	.6	.0	.0	.0
Lead arsenate	20	.0	.0	.0	.0
Lead arsenate	30	.0	.0	.0	.0
None	--	.0	.3	.6	6.5

These data indicate that all levels of lead arsenate were still effective in controlling the northern masked chafer grubs after being in the soil for 11 generations of the insect.

The data shown in Table 19 were obtained from plots that were established to determine the effectiveness of chlordane and DDT in controlling the grubs of the northern masked chafer.

The data found under the heading May 28, 1948 were obtained when the plots were surveyed 34 days after application. These results indicate that the insecticides had no effect in reducing the grub population in this short space of time. However, they were decidedly effective upon the following generation. Following the 1948 survey, the grub population was found to be less than a grub per square foot resulting in discontinuation of any further sampling in this particular area on the golf course. These meager data indicate the peculiar behavior of this insect.

TABLE 19.—Northern masked chafer control in turf, Wooster College Golf Course, Wooster, Ohio. Treatments applied April 24, 1948

Insecticide	Rate in lbs. actual per acre	Population per Square Foot	
		May 28, 1947	Sept. 27, 1948
Chlordane	15	9.6	.0
Chlordane	25	3.8	.0
DDT	25	8.4	.6
None	--	7.8	6.0

In 1951, a test was established to determine the effectiveness of chlordane when it was applied at the rate of 10 pounds of the actual material in 9, 100, or 1000 gallons of water per acre. The material was applied and was present in the turf during the time the grubs were supposedly feeding close to the soil surface. Therefore, any effect that the varying amounts of water might have upon the effectiveness of the insecticide should be indicated in the survey records. All plots were first surveyed 13 days after application and then at 7-day intervals for four different times and again a year later as shown in Table 20.

TABLE 20.—Northern masked chafer control in turf, Wooster College Golf Course, Wooster, Ohio. Treatments applied April 17, 1951

Insecticide	Rate in lbs. actual per acre	Amount of water used gals./acre	Date Surveyed and Population per Square Foot					
			April 30, 1951	May 7, 1951	May 14, 1951	May 21, 1951	May 28, 1951	May 5, 1952
Chlordane	10	1000	33.0	27.1	18 1	14 5	10.8	.0
Chlordane	10	100	19 5	20.5	17.4	11 8	13.3	.3
Chlordane	10	9	27.5	19.8	17 5	18.3	12.8	.5
None	--	----	28 8	24.3	20.8	17.8	13.8	7.5

The data indicate that the effectiveness of the chlordane was not affected by applying it in varying amounts of water in this test. The similarity in these results however indicate that the grubs were full grown and that many of them did not feed close to the surface during the period of the 1951 study. However, by May 5, 1952, all treatments were effective.

In 1951, tests to evaluate the effectiveness of chlordane, heptachlor, and toxaphene in controlling the grubs of the northern masked chafer were established in the Tam-O-Shanter Golf Course near Canton. Table 21 shows the effectiveness of the insecticides in controlling three generations of the insect. In the fall of 1953, the whole course was treated with chlordane, making it necessary to abandon these test plots.

These data are similar to those obtained when the same insecticides were applied for the control of the Japanese beetle. Again it is shown that these insecticides had little or no effect in reducing the grub population a month after an April application. However, subsequent populations were completely eliminated.

TABLE 21.—Northern masked chafer control in turf, Tam-O-Shanter Golf Course, Canton, Ohio. Treatments applied April 20, 1951

Insecticide	Rate in lbs. actual per acre	Population per Square Foot		
		May 26, 1951	May 6, 1952	Oct. 7, 1952
Chlordane	5	3.0	.0	.0
Chlordane	10	5.0	.0	.0
Chlordane	20	2.5	.0	.0
Heptachlor	5	6.8	.0	.0
Heptachlor	10	3.0	.0	.0
Heptachlor	20	4.8	.0	.0
Toxaphene	10	6.0	.0	.0
Toxaphene	20	3.0	.0	.0
Toxaphene	30	4.3	.0	.0
None	--	3.5	6.5	2.5

The relative effectiveness of toxaphene and dieldrin in controlling the larvae of the northern masked chafer is summarized in Table 22. These insecticides were in the soil for three generations of the insect.

These data indicate that these insecticides were as effective against the northern masked chafer as they were against the Japanese beetle grubs (See Table 10).

TABLE 22.—Northern masked chafer control in turf, East Liverpool Country Club, East Liverpool, Ohio. Treatments applied April 23, 1953

Insecticide	Rate in lbs. actual per acre	Population per Square Foot		
		May 21, 1953	April 27, 1954	April 19, 1955
Toxaphene	6	2 0	.5	.0
Toxaphene	18	7.0	.0	.0
Dieldrin	1	1.0	.0	.0
Dieldrin	5	2.0	.0	.0
None	--	2.5	4.0	1.5

Data shown in Table 23 came from plots that were established to determine the effectiveness of dieldrin, aldrin, heptachlor, and lead arsenate in controlling grubs of the northern masked chafer. These insecticides have been in the soil for four generations of the insect.

TABLE 23.—Northern masked chafer in turf, Greenlawn Cemetery, Nelsonville, Ohio. Treatments applied October 20, 1953

Insecticide	Rate in lbs. actual per acre	Population per Square Foot		
		April 28, 1954	Sept. 9, 1954	Oct. 2, 1956
Dieldrin	3.0	3 5	.0	.0
Aldrin	3.5	1.0	.0	.0
Heptachlor	5.0	1.3	.0	.0
Lead arsenate	435.0	3.0	.0	.0
None	----	2.5	4.0	11.4

On April 28, 1954, the results obtained in the treated plots were not significantly different from that found in the untreated areas. However, all of the insecticides were very effective in the next two surveys.

The data in Table 24 were obtained from plots that were established to determine the effectiveness of chlordane in controlling grubs when applied in the granular form at the rate of five pounds of actual material per acre. In this test the toxicant has been in the soil for three generations of the insect.

TABLE 24.—Northern masked chafer control in turf, Cemetery in Wayne County, Wooster, Ohio. Treatments applied April 23, 1956

Insecticide	Rate in lbs. actual per acre	Population per Square Foot	
		Oct. 4, 1956	Sept. 6, 1957
Chlordane	5	.0	.0
None	--	5 0	6.0

The grub population averaged six grubs per square foot in the fall of 1955. While the usual survey 30 days after application was not taken, subsequent surveys indicate that granular chlordane applied with a cyclone seeder does an excellent job of controlling the grubs when applied at five pounds per acre.

JUNE BEETLES

More than 30 species of June beetles, *Phyllophaga* spp., are found in Ohio. The adults of the different species, which vary from light brown to nearly black in color, emerge from the soil during May and June. Adults feed at night on the foliage of such trees as oak, hickory, walnut, birch, elm, willow, and many others. They hide in the soil during the day where the females lay eggs, usually in grass areas.

Eggs of these beetles when first laid are pearly-white and elongated, becoming swollen and almost spherical 6 or 7 days later. They hatch into tiny grubs in about 3 or 4 weeks.

The young grubs feed on the decaying and living vegetable matter in the soil during the first summer. As cold weather approaches, they burrow deeper into the soil, remaining there until the spring of the following year when they return near the surface to continue their feeding on the roots of plants. The grubs feed ravenously and grow rapidly throughout the second summer, causing most of the damage to turf during this year. About mid-October, they again burrow into the soil to pass the second winter. In the following spring they once more come to the surface and feed for a month or two on the roots of grasses and other plants. About the middle of June they move downward in the soil and change to the pupal stage. After spending a month as pupae, they change to adults but remain in their pupal chamber throughout the fall and winter and emerge as adults the following May and June. The female beetles begin to lay eggs in the soil shortly after emerging and thus start another cycle.

Although there is some variability among the many species of *Phyllophaga* in the length of a generation and in the time of adult emergence, the usual life cycle is shown in Figure 4.

The author has not been successful in obtaining any continuous control information from insecticide plots that were established solely for the purpose of determining the effectiveness of insecticides in controlling grubs of the June beetles. For example, a series of plots using lead arsenate, DDT, and chlordane were set up on a golf course near Logan, Ohio, in August of 1954. At the time the treatments were applied, the grub population averaged one grub per square foot. Since 1954, there has been an absence of grubs in the area. The information pertaining to the control of June beetle grubs has been obtained from plots that were established to determine the effectiveness of insecticides in controlling the grubs of the Japanese beetle and the northern masked chafer. When infestations of June beetle grubs have occurred in these plots, control data have been taken. Accordingly the data seem somewhat incomplete and sketchy, but the general information obtained is that the insecticides that will control the Japanese beetle and the northern masked chafer will also control the June beetle grubs.

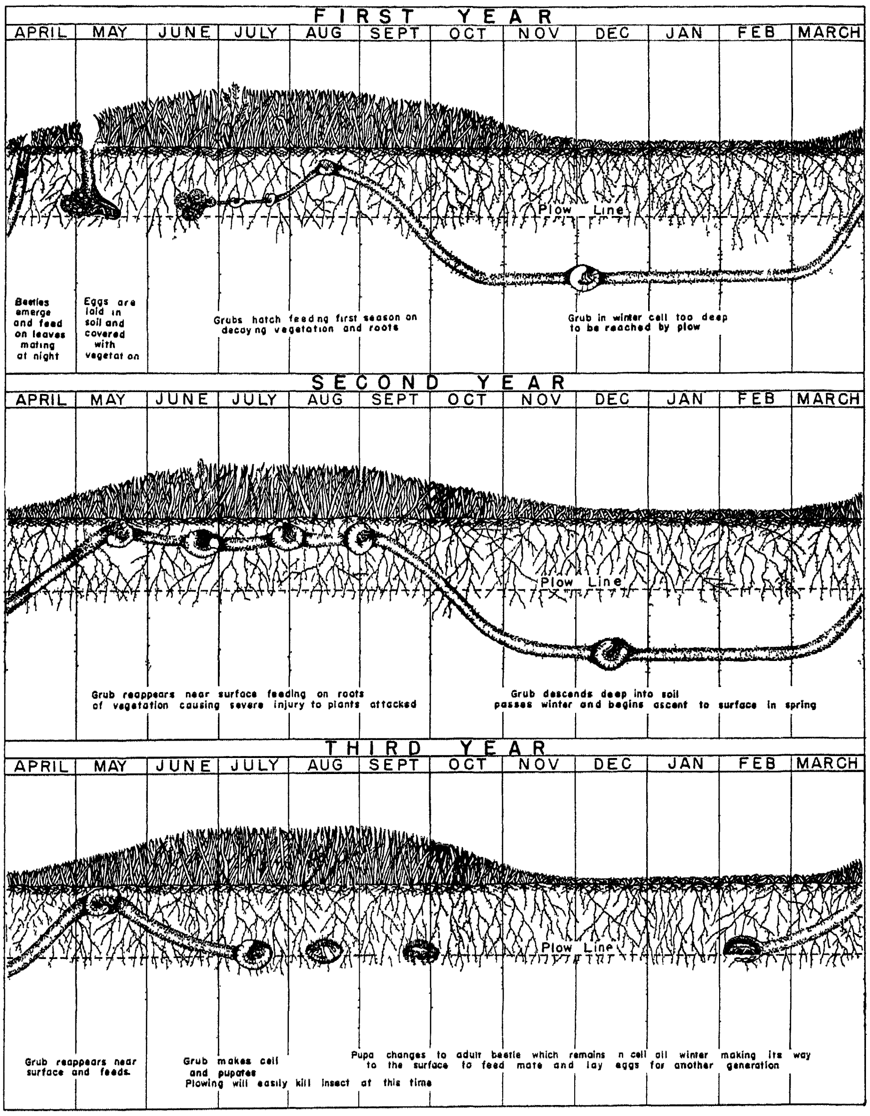

Fig. 4.—Chart showing the usual life cycle of the June beetle.

The data in Table 25 were obtained from plots that were established to study the effectiveness of insecticides for the control of the Japanese beetle grub. These materials have been in the soil for five years.

TABLE 25.—June beetle grub control in turf, New Matamoras Cemetery, New Matamoras, Ohio. Treatments applied October 21, 1953

Insecticide	Rate in lbs. actual per acre	Population per Square Foot				
		April 19, 1954	Sept. 8, 1954	May 3, 1956	Sept. 20, 1956	Oct. 7, 1957
Lead arsenate	435.0	3.0	.7	.0	.3	.3
Aldrin	3 5	1 4	.0	.0	.0	.0
Dieldrin	3 0	3 0	.0	.0	.0	.0
Toxaphene	24.0	2.7	.7	.0	.0	.0
Heptachlor	5 0	2 7	.0	.0	0	.0
None	----	4	1 4	1 0	2.7	.0

The data in the April 19, 1954 column again indicate that an insecticide applied in October has little effect upon the grub population that is in the soil at the time of the application regardless of what grub is concerned (See Tables 11 and 25). The grub population of the June beetles was not great in 1953-54, but this population in combination with that of the Japanese beetle and the northern masked chafer influenced moles to invade the cemetery and to cause considerable damage.

SUMMARY

Various insecticides were applied to turf to determine their effectiveness in controlling the grubs of the Japanese beetle, the northern masked chafer, and the June beetles. Regardless of the formulation used and the method of application employed, the results have been effective for a wide range of insecticides. However, insecticides applied in September or October or the following April or May were not as effective in eliminating the grubs that were in the soil at the time of application as they were in preventing subsequent infestations of the insect.

Some of the materials, especially chlordane at the 5 and 10 pound level and DDT at the 37.5 pound level, have given excellent control of all grubs for more than 12 years. Lead arsenate was not as consistent because in one test it ceased to be effective after being in the soil for five years while in another it was still very effective after being in the soil for 12 years. For a number of years lead arsenate was a standard turf treatment material, but within the past 10 years it has been largely replaced by the cheaper chlorinated hydrocarbons.

The results obtained from the various levels of BHC indicate that the lower levels are not effective for more than a few years and the higher levels are prohibitive on the cost-per-acre basis. Results obtained from the other chlorinated hydrocarbons, such as heptachlor, dieldrin, aldrin, and endrin, indicate that these materials are highly effective and should be considered in any grub control program.

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